HARVEY ENGINEERING LABORATORIES for Research & Development
DIVISION OF HARVEY
TORRANCE CALIFORNIA

HA NO 2190 PAGE Cover

Progress Report No. 6

DEVELOPMENT OF CONTROLS FOR TIME-TEMPERATURE CHARACTERISTICS IN ALUMINUM WELDMENTS

CONTRACT NO. NAS8-11930
Control No. DCN1-5-30-12723-01

Covering Period
From September 1, 1965 thru September 30, 1965

Prepared for

George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Huntsville, Alabama

October 10, 1965

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ABSTRACT

This report contains a summary of accomplishments during the first six months of a two phase research program to develop methods, tooling concepts, and processes to control the time-temperature characteristics in the weld and heat affected zone, in order to improve tensile properties and reduce porosity in aluminum weldments.

The results of the first phase, which consisted of a survey of literature and industry, were reported in August. Equipment has been modified, with instrumentation installed to monitor welding variables. An evaluation of radiometers for application to the program was started. Reference Weldments, without chilling, were made in 5/16" and 1/2" thick plate. Preliminary studies, using liquid CO_2, indicated adequate chilling can be effected to alter weld thermal patterns.

I. ACCOMPLISHMENTS PREVIOUSLY REPORTED

A. Summary

During the four month period of Phase I, 63 reports of previous work in related fields were reviewed, and 17 industrial and governmental organizations were contacted. By combining the pertinent information from this survey with the original technical concept, a program plan was developed for the experimental work to be performed in Phase II. Materials of long lead time delivery have been procured and preliminary modification of equipment has progressed to the point where experimental work can be initiated.

B. Literature Reviewed

The purpose of the survey was to obtain information which might be helpful in the performance of this program, by avoiding duplication of effort and/or by supplementing the original program concept.

Current abstract bulletins published by the National Aeronautics and Space Administration (STAR) and by the Defense Documentation Center (TAB) were checked for reports of work pertinent to fusion welding of aluminum, and significant reports were acquired for review. A similar survey was made of applicable technical books and periodicals, including those of the American Welding Society, the American Society for Metals and the American Institute of Mining and Metallurgical Engineers. Particular emphasis was devoted to issues of the Welding Journal published during the past ten years.

cast structure was obtained. All of this work was performed on 0.090" thick 2014 and 2024 aluminum alloys. In one set of experiments the chill bars (both top and bottom) were cooled with brine at -45°F. In a second set, for which data has just been published, the chill bars were cooled with liquid nitrogen. In each case, welding was performed after the parts to be welded reached a selected temperature, -30°F. and 250°F. respectively. Difficulty with condensation of moisture on the parts was overcome by enclosing the part in a flexible plastic bag containing dry argon or helium.

A large amount of work has been done and is currently in progress to improve the quality of weldments in aerospace components fabricated from aluminum. Although only a few specific studies have apparently been conducted on a laboratory basis for determining the effect of time-temperature on properties of weldments, a good many of the process controls adopted for shop welding are aimed in the direction of controlling thermal patterns.

D. Experimental Program

The experimental program will consist of two essential steps. The first will be to establish realistic target thermal patterns designed to improve the weld properties, and the second will be to devise and test various means of providing the time-temperature controls required to attain the optimum thermal patterns for welding the plate in two thicknesses, 1/2" and 5/16", in each of two alloys, 2014-T6 and 2219-T87. Welding will be performed in the horizontal position by the Semi-Automatic TIG process, using direct current straight polarity, on square butt joint preparation, with 2319 filler wire. It is contemplated that cryogenic liquids and auxiliary heat sources will be used to alter thermal patterns during welding. Tensile tests and hardness surveys will be used to correlate mechanical properties with thermal pattern.

Sixty-three reports were selected for review and were classified under three general subject areas according to their principal interest to this program: (1) Time-Temperature Studies, (2) Heat Flow During Welding, and (3) General Welding Techniques.

No reported or unreported work was found which would indicate that any part of this program is a duplication of effort. A considerable amount of information was obtained which will facilitate the experimental portion of the program, particularly that work pertaining to heat transfer analysis and specific welding techniques currently in use for fabricating aerospace structures by welding the particular materials involved.

C. Organizations Contacted

Those organizations and individuals who were considered to be involved in work related to this program were contacted for personal interview or for interview by telephone. The cooperation was excellent, and in some cases special data were furnished and tours of plant facilities were arranged. In general, a great deal of interest was expressed in this program.

It appears that at the present time, no specific work is in progress to develop data in addition to that already reported in the literature for development of time-temperature controls or theoretical heat flow information for welding of aluminum alloys.

However, in some work recently completed at Frankford Arsenal it was determined that three significant trends were noted in the microstructure which indicate the merit of the use of super-chilling during welding of aluminum: (1) the amount of micro-porosity was substantially lessened, (2) the width of the zone of grain boundary melting at the interface was reduced appreciably, and (3) a finer grained

II. ACCOMPLISHMENTS DURING THIS REPORT PERIOD

A. Summary

The principal effort during this reporting period was devoted to finalization of equipment modification, and instrumentation of principal welding variables. Preliminary steps were taken for evaluation of infrared radiometers applicable to the program. Welding of 2014-T6 plate without special chilling, but with monitored welding variables was begun. Initial experiments on chilling indicated that liquid CO_2 is capable of extracting a sufficient amount of heat to alter the thermal patterns in the weldment.

B. Modification of Equipment

1. General

The welding equipment was supplemented and modified so that experimental welding could be started. Additional modifications were effected to provide heat extraction from the back side of the weld by means of liquid CO_2 jets, and for scanning the weld area by means of infrared radiometers to measure thermal patterns.

2. Welding Equipment

a. General

Equipment has been set up so that welding can be performed in the "free" state in the horizontal position. Test panels 12" x 48" are welded from one side only, using the square butt edge preparation. Helium shielding gas is used on the arc side, and 2319 filler wire will be used as required to obtain acceptable bead contour.

b. Welding Power Supply

A duplex Miller DC rectifier type welder, Model No. 600/1200, with superimposed high frequency, is used to supply the welding current.

c. Side Beam and Carriage System

A 12 ft. Berkeley-Davis System Model No. TC4 has been mounted on a rectangular support frame fabricated from 2-1/2" diameter tubular steel pipe which is anchored to the floor and to the building structural members. The side beam carriage speed is controlled by an electronic governor (Model EG-3) for travel speeds ranging from 4.4 to 72.01 inches per minute.

d. Welding Torch

An Airco HP-50A Heliweld holder with metallic nozzle of 5/8" and 1/2" orifices has been adapted for semi-automatic welding using 5/32" and 3/16", 2% thoriated tungsten electrodes.

e. Wire Feed

An Airco filler wire feed with wire positioner has been installed on the carriage system and fitted for 3/64" and 1/16" wire.

f. Panel Fixture

The fixture for positioning the weld panels in the horizontal position consists of a frame fabricated from 1/4" x 3" x 3" angle iron, with a "free" area of 4 inches on each side of the weld centerline. The panels are clamped to the fixture by means of angle clamps which were machined for each thickness.

2. Chilling System

Jets of various orifice size, flexible hose, and a 250 lb. tank of liquid CO_2 were obtained. An attachment bracket for positioning the jets was mounted on the back side of the weld carriage system. The location and number of jets are adjustable.

C. Instrumentation

1. General

Instrumentation has been set up to monitor all variables which are significant to this program, including welding speed, welding current, and time-temperature patterns.

2. Welding Speed

An optical tachometer, utilizing light reflections from the carriage drive motor shaft, is used to monitor welding speed. The reflected light is directed into a photocell, the signal from which is converted into revolutions per minute by a Hewlett-Packard Frequency Meter, Model 50CC. This motor speed is then calibrated in terms of travel speed in inches per minute.

3. Welding Current

A Weston D.C. Ammeter, Model 1, with a 750 amp. shunt, was installed in the workpiece ground lead, which, in conjunction with a Weston D.C. Voltmeter Model 1, monitors the welding current.

4. Time-Temperature

A Leeds & Northrup Speedomax 12-channel recorder was modified to accomodate the required temperature range (-300 to 2100°F), using chromel-constantan thermocouples.

A Huggins Mark I Infrascope (infrared radiometer) and a Barnes scanning radiometer (also infrared) were obtained for evaluation. Several other manufacturers of similar non-contact temperature measuring systems were also contacted. Preliminary evaluations indicate that the infrared radiometers will be useful in transient weld temperatures during welding. Due to their extremely rapid response to temperature changes, they appear to be much superior to systems utilizing thermocouples. They are also capable of a much greater versatility from the standpoint of continuous temperature monitoring of points of fixed distances from the arc. The major disadvantages appear to be sensitivity to changes in surface conditions (emissivity) of the weldment, and cost. The price of a suitable fixed spot infrared radiometer is approximately $1,000. The cost of scanning radiometers appears to vary from approximately $4,500 to $15,000 (most of these are made to order). The problem of emissivity changes can be overcome by the use of a coating (such as colloidal graphite), and some initial tests indicated that this method might be applicable to welds - at least on the back side. Another possible solution to the emissivity problem might be the use of the "two-color" radiometers. This type will be investigated during the next reporting period.

D. Experimental Work

1. Establishment of Reference Welding Parameters

a. General

In order to establish reference data to which future experimental welding will be compared, weldments in each of the aluminum plate materials were fabricated under monitored conditions without the use of chilling. The thermal pattern data in connection with the mechanical and metallurgical characteristics of these weldments will be used as the starting point for alteration of thermal patterns to improve the properties.

b. Reference Weldments in 2014-T6 Plate

Weldments of satisfactory physical appearance were produced in 5/16" thick and 1/2" thick plate using the following welding parameters:

Thickness	Amp.	Volts	Weld Travel
5/16"	250	14	9.0 ipm
1/2"	300	18	6.5 ipm

These weldments will be examined and tested during the next reporting period.

2. Preliminary Check-out of Cryogenic System

Preliminary trials of the liquid CO_2 system indicated that more than adequate chilling effects can be obtained on the back side of the weld. A 250 lb. container with flexible delivery tube and a variety of nozzles with orifice sizes from 0.008" to 0.032" have been received. Evaluations will be continued during the next reporting period to establish basic operating parameters for the experimental work.

III. ANTICIPATED WORK FOR NEXT PERIOD

During the next reporting period, it is expected that thermal patterns and properties will be established for unchilled weldments; evaluation of radiometers will be continued; and that initial thermal patterns, altered by chilling, will be produced.

IV. SCHEDULE AND PROBLEMS ENCOUNTERED

The schedule shown on the following page remains unchanged.

A total of 356 man-hours of effort were expended during this report period, with the approximate distribution to the various functions as shown below:

Function	Engineering Hours %	Engineering Hours Hrs.	Shop Hours %	Shop Hours Hrs.
Survey	5	10	---	---
Design	25	52	---	---
Development	65	134	100	150
Documentation	5	10	---	---
TOTAL	100	206	100	150